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Review

Dissemination of cooking energy alternatives in India—a review

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Abstract

Energy requirements for cooking account for 36% of total primary energy consumption in India. The rural and urban populaces, depend mainly, on non-commercial fuels to meet their energy needs. Diverse urban growth patterns have led to structural changes in economy, and have important ramifications on energy consumption in household sector. It is observed that India follows income-based ladder starting with fuelwood and ending with sophisticated fuels like liquefied petroleum gas (LPG) and electricity. This paper discusses cooking energy dissemination in the country with an objective of understanding the underlying socioeconomic factors governing the utilization of various fuels/energy carriers in cooking. The diffusion of renewable energy devices is observed to be far below their estimated potential. Policy interventions required for better dissemination of renewable energy based devices are also discussed.

Keywords: Cooking energy; Dissemination; Solar cookers; Renewable energy

Contents

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1. Introduction

Domestic sector is one of the largest consumers of primary energy in India (nearly 40% of total energy demand), and traditional sources still dominate the sector. Ninety percentage of the household energy consumption is for cooking alone. The demand for cooking energy is increasing annually at a rate of 8.1%. In house-hold sector, 75% of energy requirements are met by fuelwood and agriculture waste; the rest is met by kerosene and liquefied petroleum gas (LPG) [1].

The world primary energy consumption in 2000/2001 was 403.92 quadrillion (10^{15}) BTU against a production of 403.44 quadrillion BTU [2]. This situation is even worse in developing countries like India. Though the primary energy consumption was 3% of the world energy consumption during 2000–2001, increasing population at a rate of 2.1% per annum has resulted in increasing the gap between demand and supply of energy [3]. India mainly depends on coal, oil, and fuelwood for most of its energy needs. After the first oil shock in 1973, energy sector emerged as a crucial and dynamic component of the Indian economy.

The type of fuel used by a household varies with income. Low-income group depends mainly on firewood (in rural as well as urban areas) while the middle-income group depends on fuelwood in rural areas, and urban areas on kerosene. The high-income groups depend mainly on LPG in urban areas. Statistics derived from a series of studies of the National Sample Survey Organization (NSSO) provide information on the use of various fuels in different classes of expenditure [4,5]. Accessibility of LPG in rural areas is very poor and only 1.3% of rural masses get LPG through distribution network [3]. It is also

observed that 90% of rural households are still dependent on biomass fuels suck as fuelwood, cow dung, and agricultural residue [6].

In this scenario, renewable energy can emerge as one of the strong contenders to improve the plight of people. Efforts have been made to develop and disseminate renewable energy technologies such as biogas stoves and improved cookstoves to have an efficient utilization of bio-fuels for domestic cooking. Attempts have also been made to supplement the existing options with various versions of solar cookers, but the level of dissemination has been found to be below the estimated potential [7–9].

2. Trends in household energy consumption

Historical trends in household energy consumption for the period 1950–2000 are presented in Table 1. The most notable observation is the decline in the share of non-commercial fuels. These fuels accounted for 97% of the total consumption in 1950, but had declined to about 80% in 2000. The data also demonstrate an increased share of LPG and electricity as the main fuels from 0.06% in 1950 to 10.34% in 2000. The growth of kerosene, however, remained steady over the 50-year period. Though the difference between the share of commercial and non-commercial fuels decreased substantially, it remains considerable. Many house-holds that used to depend on fuelwood have shifted to modern energy carriers like LPG and electricity. This higher share of fuelwood and other biomass resources is a consequence of lower energy efficiency of utilization. Major factors for these shifts are the levels of urbanization, economic development, and living standards. This has resulted in a lower growth rate of fuelwood consumption (3.7% per annum). LPG and electricity had achieved growth rates of 35.8 and 23.8%, respectively [10]. The pattern of household energy consumption is region specific, depends on the income of the household, availability of local resources, alternative fuels and price of fuels, etc. [11]. There is a variation in the contribution of different energy carriers to the energy mix of

Table 1
Energy consumption in Indian household sector (MTOE) (1950–2000) [10]

Fuel/energy carrier	1950	Percentage of total	1960	1970	1980	1990	2000	Percentage of total	Annual growth rate (%)
Fuelwood	54.08	82.65	67.1	84.65	88.1	84.43	114	75.60	3.7
Coal/charcoal	0.77	1.18	1.08	1.36	2.12	2.03	2.5	1.66	6.7
Kerosene	1.12	1.71	2.76	3.48	5.24	5.02	12.5	8.29	11.5
LPG		0.00		0.00	1.2	1.15	6.4	4.24	35.8
Electricity	0.06	0.09	0.13	0.16	0.79	0.76	9.2	6.10	23.8
Others	9.4	14.37	8.2	10.34	6.9	6.61	6.2	4.11	−2.3
Total	65.43	100.00	79.27	100.00	104.35	100.00	151.8	100	3.9

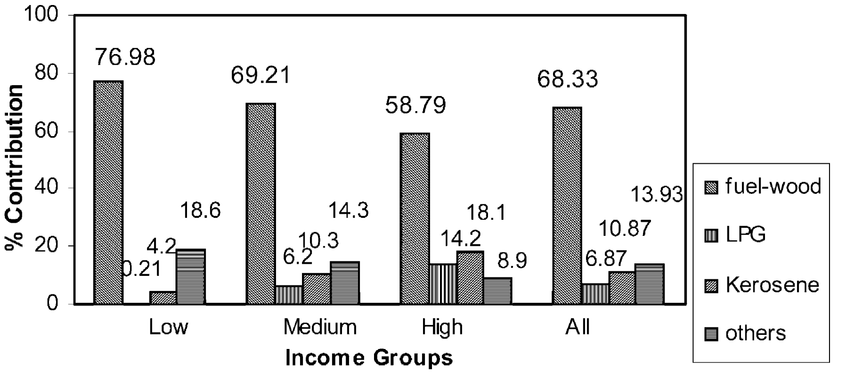


Fig. 1. Share of rural households using particular energy carrier for cooking (2000–2001) [10].

different income groups. Figs. 1 and 2 indicate the share of rural and urban households using particular fuel/energy for cooking applications.

3. Current cooking energy options

A variety of energy sources like commercial and non-commercial, renewable and non-renewable are used in India. They are discussed below.

3.1. Fuelwood

Forest cover over India is estimated to be 6,75,538 km^2 which is 20.55% of its geographical area, and the sustainable production of fuelwood from different sources is about 122 million tonnes (MT) against the estimated national consumption of 168 MT [12,13]. It is the most preferred option of rural masses because of easy availability from either their own fields or the forest either at low-cost or free of cost. Generally, women and

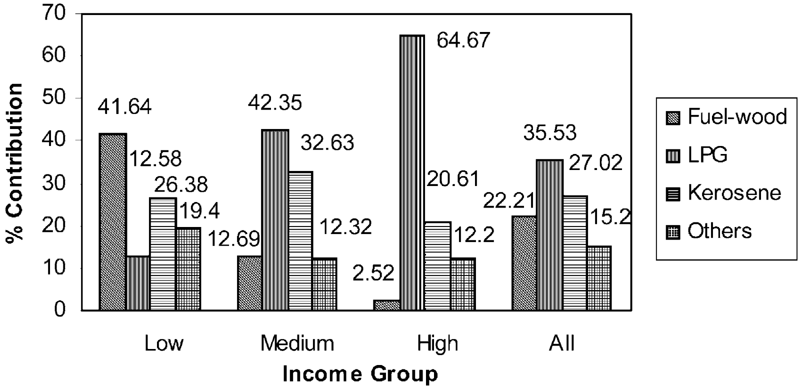


Fig. 2. Share of urban households using particular energy carrier for cooking (2000–2001) [10].

female children are involved in the collection and transportation of fuelwood. Fuelwood is burnt for cooking for use in low-cost, easy to construct and rugged devices like traditional *chulhas* (cookstoves) and sometimes in improved *chulhas*. The traditional use of fuelwood has many drawbacks such as, indoor air pollution, health hazard to women and children, and hardship in collecting the same. The drudgery in terms of cleaning utensils and missed education opportunities for female children is an issue of concern in many developing countries like India [14,15].

3.2. Kerosene

Kerosene is distributed through public distribution system (PDS), and is mostly used by low and middle-income group families. Kerosene stoves are popular due to their efficient, quick, easily controllable, convenient features as compared to other rural cooking devices. On the other hand, kerosene stoves give off an unpleasant smell. The safety of kerosene stoves is also questionable. Lighting kerosene stove is also tedious. The government is providing a flat subsidy of Rs. 2.45/- on every liter of PDS kerosene [16]. The total kerosene consumption in India during 2000/2001 was estimated at around 10.5 MT, out of which about 60% of the total consumption was for rural areas and the rest for urban areas. Nonavailability of kerosene for the households is a major issue [17].

3.3. Liquefied petroleum gas

The marketing of LPG in India started way back in 1955–1956. The production of LPG during 2000–2001 was 6148×10^3 MT. A major portion of the Indian population (58%), accounting for 75 million consumers approximately, were using LPG in the year 2000, amounting to 8 MT of LPG consumption. The government is providing a flat subsidy of Rs. 67.75/- on every LPG cylinder for domestic use since April 2002 [18]. Public sector oil companies are mostly engaged in its distribution. This cooking fuel enjoys the highest degree of popularity in urban areas because of a number of advantages like cleanliness, safety, efficiency, cost effectiveness. It is much easier to use and ignite, easy to store and transport, and has the highest calorific value. But it is mostly used amongst middle- and high-income groups in urban areas due to its poor distribution network in rural areas and increasing cost. Due to the high initial cost of appliances, risk of explosion, and poor distribution network, it is not widely used in the majority of poorer areas.

3.4. Electricity

Eighty-seven percentage of the Indian villages are electrified, with 10 states having 100% electrical connectivity [19]. This high-grade energy option uses microwave ovens, hot plates and is limited to upper class families in urban areas due to the high initial costs of equipment and recurring costs. Electricity as a cooking energy option has a number of advantages like cleanliness, easy to use, high standard of living, no drudgery, high-conversion efficiency. However, safety of the electrical devices, nutrient content of the cooked food is questionable [20]. Continuous and reliable electricity supply is still beyond the reach of the Indian rural population.

3.5. Biogas

India has a potential of 12 million biogas plants [21]. Biogas (a mixture of methane and carbon-dioxide) is produced through the anaerobic fermentation of biomass such as cow dung, human waste and other organic wastes in the absence of oxygen in cylindrical digesters (fixed dome and floating drum). Biogas, thus produced, is taken from the outlet and used for cooking and other purposes. Use of biogas for cooking leads to cleanliness with no health hazard, and improved quality of life. It also promotes optimal utilization of the natural resources of dung (energy produced is three times more useful than that produced by direct burning) [22]. However, there are certain issues like technology upgradation, reduction in initial costs, behavioral issues associated with the use of this technology for cooking.

3.6. Biomass

Plant biomass such as leaves, grasses, weeds, agricultural waste, etc. represents stored energy, which is used for cooking purposes after converting it into various forms like producer gas, fuel briquettes, and charcoal. India generates about 600 MT of agrowaste annually, and the total biomass growth from various resources such as social forestry, agriculture, village forest, wastelands, etc. is estimated at 1665.4 MT per annum. [12]. The main obstacle in its utilization is the distribution and availability. The cost of collecting and transporting it to a central processing facility is thus prohibitively high. Also due to less awareness and developing nature of technology, it is not a popular cooking energy alternative.

3.7. Solar energy

India is blessed with good sunshine. Most of the parts of the country receive mean daily solar radiation in the range of 5–7 kW h/m^2, and have more than 275 sunny days in a year [23]. Hence, solar cooking has a high potential of diffusion in the country, and offers a viable option in the domestic sector. It is identified as an appropriate technology for Indian masses, and has numerous advantages such as no recurring costs, potential to reduce drudgery, high nutritional value of food, high durability, etc. In spite of these advantages, the main hurdles in its dissemination are reluctance to acceptance as it is a novel technology, intermittent nature of sunshine, limited space availability in urban areas, higher initial costs and convenience issues. The growing urban lifestyle also warrants faster cooking which is not possible in box solar cookers [24,25].

4. India's cooking energy scenario

This section presents data on household energy consumption for various income categories for rural and urban regions. Though income primarily decides the choice of cooking fuel, other factors such as availability, market network, after sales service and several behavioral issues decide the choice. With increasing disposable income and changes

Table 2
Share of households using particular energy carrier for cooking (1999–2000) [1]

Expenditure class	Fuelwood	LPG	Dung	Kerosene	Coal	Biogas	Electricity	Others	Total
Rural households									
Low income	29.24	0.16	3.85	0.24	0.61	0.01	0.00	1.37	35.5
Middle income	39.36	2.14	5.59	1.35	0.72	0.15	0.04	1.66	51.0
High income	6.95	3.10	1.18	1.12	0.23	0.16	0.04	0.73	13.5
Total	75.54	5.40	10.62	2.71	1.56	0.32	0.08	3.77	100.0
Urban households									
Low income	15.24	5.04	1.26	7.13	2.08	0.01	0.08	1.92	32.8
Middle income	6.81	28.16	0.76	13.11	2.07	0.04	0.25	1.98	53.2
High income	0.25	11.01	0.04	1.50	0.10	0.00	0.08	1.09	14.1
Total	22.29	44.21	2.06	21.74	4.25	0.05	0.40	4.99	100.0

(*continued on next page*)

in lifestyles, households tend to move from the cheapest and least convenient fuels (fuelwood, dung, etc.) to more convenient and normally more expensive ones (kerosene), and eventually to the most convenient and usually most expensive types (LPG and electricity). This suggests a significant increase in the efficiency of energy utilization. Table 2 presents the share of households using particular energy carrier for cooking during 1999–2000.

4.1. Scenario in urban household sector

Out of a total 19.20 million households in India, nearly 5.37 million reside in urban areas [26]. According to a study projection, the total household energy demand in urban areas is constantly increasing, and has increased from 69.57 MTCR (million tonnes of coal replacement) in 1994/1995 to 86.72 MTCR in 1999/2000. A study on the pattern of per capita energy use in the urban areas of Maharashtra and Uttar Pradesh States revealed that cooking accounts for 92% of the gross energy consumption by the poor, while it forms only 60–70% of the total energy use for the high-income groups. These data are indicative of those of other states in the country. It is also observed that high-income groups not only used more energy per capita, but also use high quality and clean fuels such as LPG and electricity. The per capita monthly consumption of fuelwood and chips in urban areas has increased from 6.09 kg in 1993/1994 to 6.45 kg in 1999/2000 (Table 3). The trend shows that in urban areas, poor households are still dependent upon traditional fuels for their energy needs. The same increasing trend is also observed in per capita consumption of electricity that has increased substantially from 9.67 kW h in 1993/1994 to 22 kW h in 1999/2000. The per

Table 3
Monthly per capita consumption of various fuels in India (1999–2000) [3]

Fuel	Urban	Rural
Fuelwood and chips (kg)	6.45	17.4
Electricity[a] (kW h)	22.0	6.35
Kerosene[a] (l)	0.68	0.61
LPG (kg)	1.45	0.37

[a] Includes lighting and decrease in consumption of kerosene is due to electrification.

capita consumption of kerosene has decreased in urban areas from 1.42 l in 1993/1994 to 0.68 l in 1999/2000. In urban areas, households using, mainly three sources, fuelwood, kerosene, and LPG, as primary sources of energy for cooking [3]. On comparing results from the 50th and 55th rounds of the NSSO, it has been observed that though the consumption of fuelwood for cooking has decreased in urban areas, the consumption is still substantial (Fig. 3). Households (22.3%) use fuelwood and chips as a primary source of energy for cooking. LPG is found to be the main source with 44.2% of households using it as a primary source for cooking. There is marginal decrease in the use of kerosene during this period [4,5].

4.2. Scenario in rural household sector

Out of the total households, nearly 13.83 million are in rural areas [26]. A study on the energy-using household activities in six states found traditional fuels as the largest contributor to energy use in rural areas, while commercial fuels for cooking are limited. Fig. 4 shows a slight increase in the monthly per capita energy consumption of fuelwood from 1993/1994 to 1999/2000, and increase in consumption of electricity. There is a decrease in the consumption of kerosene, which is used mainly for lighting and this decrease is due to electrification. Only 2% of rural households in India use kerosene as the primary source of fuel for cooking. As shown in Fig. 5, 86.1% of the rural households use fuelwood and dung for cooking [4,5]. In comparison of the last two NSSO rounds, it is found that with the increase in the supply commercial energy sources, there is a slight

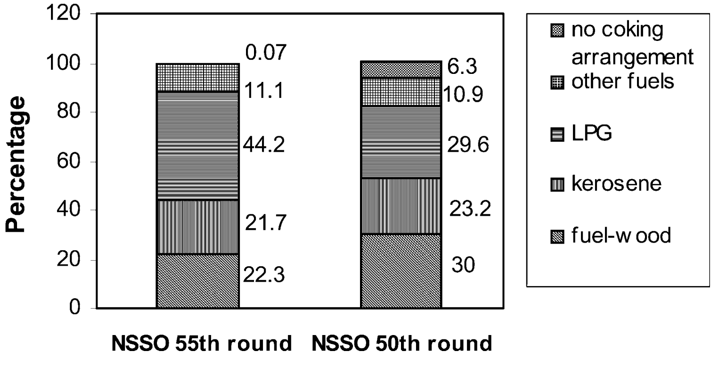


Fig. 3. Distribution of households by primary source of energy used for cooking in urban areas [4,5].

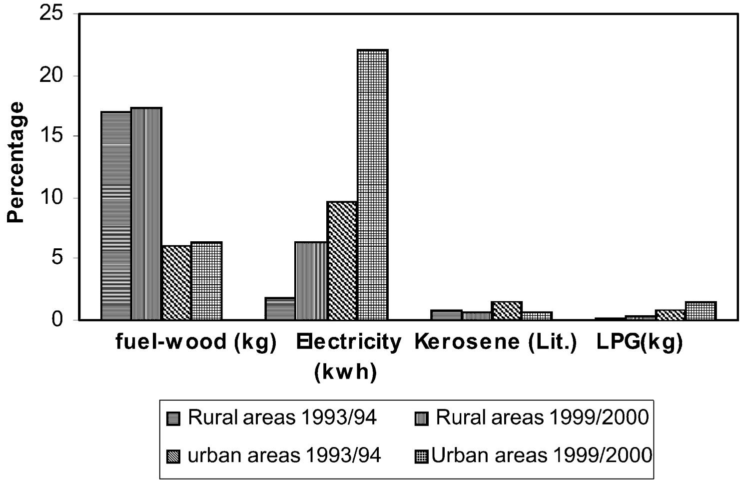


Fig. 4. Monthly per capita consumption of energy sources [3].

decrease in the consumption of biomass based fuels for cooking, and a slight penetration of LPG in the rural areas with an increase of 3.5%. In spite of a significant increase in the supply of commercial energy, the consumption of commercial fuels such as LPG is still negligible in rural areas [27].

5. Trends in dissemination of cooking fuels and devices

Since a majority of rural masses gather fuelwood and, therefore, do not have to incur cost, their first choice is always biomass. The estimated annual consumption of fuelwood is much higher than the recorded production in country. Biomass energy use in

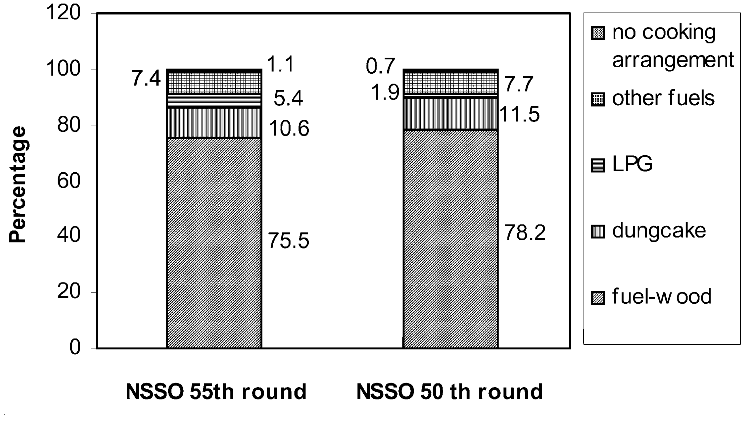


Fig. 5. Distribution of household by primary source of energy used for cooking in rural areas [4,5].

Table 4
Efficiency and average life of different fuel–device combinations [29]

Serial no.	Fuel–device	Efficiency (%)	Life (years)
1	Wood–three stone	15.7	3
2	Wood–traditional three pan	14.2	3
3	Biogas–KVIC burner	45.1	3
4	Kerosene–Nutan	60.2	7
5	Kerosene–Perfect	40.4	7
6	LPG–Super flame	60.4	20
7	Electricity–hotplate	71.3	7

India is 13–23 MJ per capita per day [28]. However, the use of biomass is associated with drudgery in gathering and in its use leading to low quality of life apart from an adverse impact on forest and village tree resources. It is important to consider fuel–device combinations which can be used in different devices with an efficiency varying from 5 to 45% [29]. Several respiratory and chronic diseases in developing countries have been attributed to higher levels of indoor pollution. It is very well accepted that traditional cookstoves using non-commercial fuels in domestic *chulhas* release a variety of pollutants in the indoor environment [30,31]. Acute respiratory infection (ARI) is one such disease responsible for the death of 5 million children below the age of 5 years worldwide every year [32]. Table 4 gives the percentage of heat utilization/efficiency and the life of various fuel–device combinations.

There are basically two types of improved *chulhas*, viz. fixed mud *chulhas* (with chimney) and portable metal *chulhas* (without chimney). In India, the National Programme on Improved *Chulhas* (NPIC) was started by the Ministry of Non-conventional. Energy Sources (MNES) in 1985–1986. There are more than 20 models of improved *chulhas* developed and are in use in developing countries. Improved *chulhas* have not been disseminated in India much; the number of installations being 35 million [33]. Fig. 6 indicates the year-wise installation of improved *chulhas* in India.

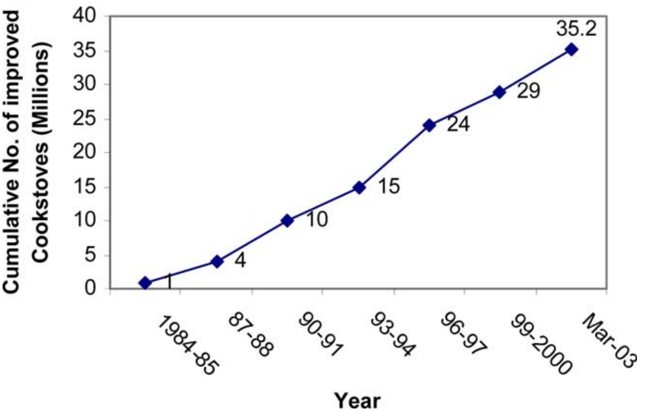


Fig. 6. Year-wise installation of improved cookstoves in India [21,34].

Table 5
Year-wise LPG consumption in India (past and projected) [35]

Period	Consumption ($\times 10^3$ tonnes)	Annual increase (%)
1980–1981	405	–
1985–1986	1241	41
1990–1991	2415	19
1992–1993	2866	9
1994–1995	3434	6
1995–1996	3849	12
1996–1997	4198	9
1997–1998	4660	11
1998–1999	5027	8
1999–2000	5902	17
2000–2001	6500	10
2001–2002	7300	12
2006–2007	10,148	8
2010–2011	12,325	5

Kerosene stoves occupy a place between *chulhas* and LPG in the consumer ladder, i.e. their primary users are largely from lower-middle and lower class. While the sales of LPG have gone up at an average rate of 13% per annum, kerosene sales have increased at the rate of 4.6% per annum. The traditional kerosene cook-stoves cost nearly Rs. 125/- and have a life of 7 years. Improved kerosene wick stoves can have up to 30 or 40 wicks and produce a maximum power of around 5 kW with an efficiency of up to 50%. The kerosene pressure stove has a maximum power output of 3–10 kW [34].

In spite of a significant increase in the supply of commercial energy, the consumption of commercial fuels such as LPG is still negligible in rural areas with only 1.3% of households using it for cooking. The numbers of customers of LPG were 62.2 million till January 2001 [35]. Table 5 shows year-wise consumption in India in the past and the projected figures.

Efforts have been made in India to develop and disseminate renewable energy technologies such as biogas, improved *chulhas*, solar box cookers, and parabolic solar cookers for the domestic cooking sector. Though the use of biogas is increasing at a brisk rate, it has not been able to replace traditional *chulhas*. According to a survey conducted by the United Nations' Food and Agriculture

Organization-Regional Wood Energy Development Programme (FAO-RWEDP), increase in biogas energy consumption in India during 1981–1991 was 30.4%. The government has been supporting biogas use since 1981, through the National Programme on Biogas Development (NPBD), and the number of installed biogas plants at the end of March 2003 was 3.523 million [36]. Fig. 7 indicates the year-wise installation of biogas plants in India.

In spite of the significant success reported in the case of biogas plants, and improved *chulhas*, solar cooker dissemination is far below the estimated potential. The different types of solar cookers developed include box solar cooker, steam cooker, solar meal maker with heat storage, concentrating type domestic and community cooker. The primary focus, however, has been on the box solar cooker programme due to its various advantages over

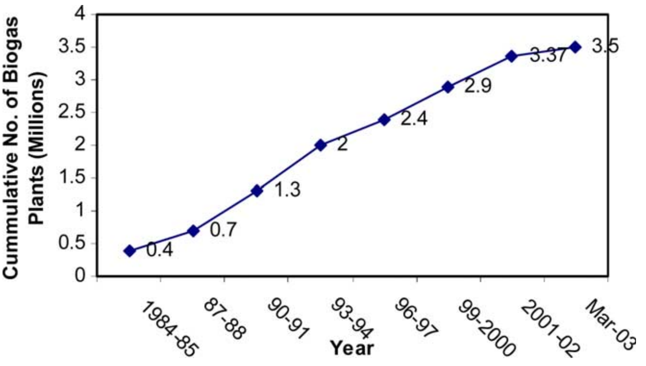


Fig. 7. Year-wise installation of biogas plants in India [21,34].

others. Efforts to develop and promote solar cookers with electrical back up to enable cooking during non-sunshine hours/cloudy days with very nominal consumption of electricity, indoor cooking with concentrating collectors, parabolic solar cookers, community steam cooking systems are amongst the programmes of the Ministry. Financing through local banks, co-operative societies and Indian Renewable Agency Development Agency (IREDA) is also a feature of the solar cooker programme of the Government of India [37–39]. Fig. 8 indicates the year-wise installation of solar cookers in India. Over 5,30,000 of solar cookers had been sold in the country till December 2002. Around 30 manufacturers are involved in the fabrication of solar cookers [36].

6. Need of policy intervention

The above discussion reveals the need of policy interventions in order to ensure sustainable household energy supply in cooking as well as removing disparity amongst

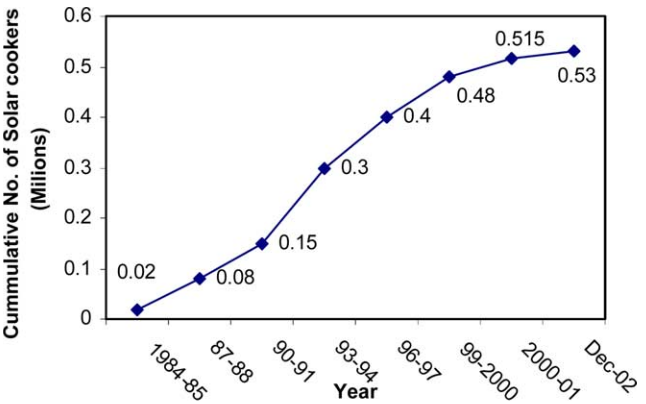


Fig. 8. Year-wise installation of solar cookers in India [21,34].

rural and urban masses, rich and poor, etc. India with a large decentralized population is an ideal location for disseminating renewable energy technologies. The economic and environmental impacts associated with the use of renewable energy represent a potent area of opportunity for individual consumers as well as to the society. With low educational levels and poor purchasing power, the dissemination of these devices remains a tough task [40]. In households, limited awareness is accompanied by limited motivation, even if energy costs are within affordable limits. But purchasing power need not be the only criterion for choice/selection/preference of cooking device. The costs of efficiency improvements are to be met by households whose preference is to invest in consumer durables rather than on energy efficient technologies. Under these circumstances, the government has to revisit renewable energy programmes to overcome consumer inertia. Renewable energy devices appear to follow technology push theory of innovation and not the demand pull. A long-term reliable goal appears to be the missing link in the policy. Though technical quality is necessary and is emphasized, it is not the only criterion for efficacy of the dissemination programme [41]. The efficacy of dissemination strategies in the present Indian context should not be considered in isolation but in contrast with the other cooking energy options available to the users. In view of the above, it is necessary to follow certain principles which are true for any household energy technology in general and cooking devices in particular. The dissemination programme should have an objective of assuring adequate supply of energy in environment friendly and socially acceptable manner. The benefits should occur at user level and not necessarily at national or regional level which are assured anyway by the effective implementation of the programme. It has been proved in many cases that wherever subsidies are offered, quality suffers as the main accent is to minimize the cost. Technology has to compete with conventional cooking energy technologies. Development and dissemination of cooking energy devices should address technical requirements and support, needs orientation, integration into socio-cultural setting, participatory approach by masses, social and environmental sustainability as a goal, training and learning from experience and intensive follow up.

7. Conclusions

Cooking energy plays an important role in sustainable energy management in Indian households. There are various options to meet the end user needs using both commercial and non-commercial energies. Traditional fuelwood utilization must be minimized with a better dissemination of improved *chulhas*, biomass and biogas development. This will lead to reduction in human drudgery. A considerable amount of socio-economic gain can be reaped with better dissemination of various cooking energy alternatives such as solar cookers. The dissemination programme of renewable energy devices needs to be revisited with an approach of improving their total usefulness, in terms of techno-economic, social, behavioral, and commercial aspects. Such an effort will not only be useful in improving the quality of life but also in environmental protection.

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